BGS INSTITUTE OF TECHNOLOGY

Digital Signal Processing (DSP) Fundamentals

Presented by,

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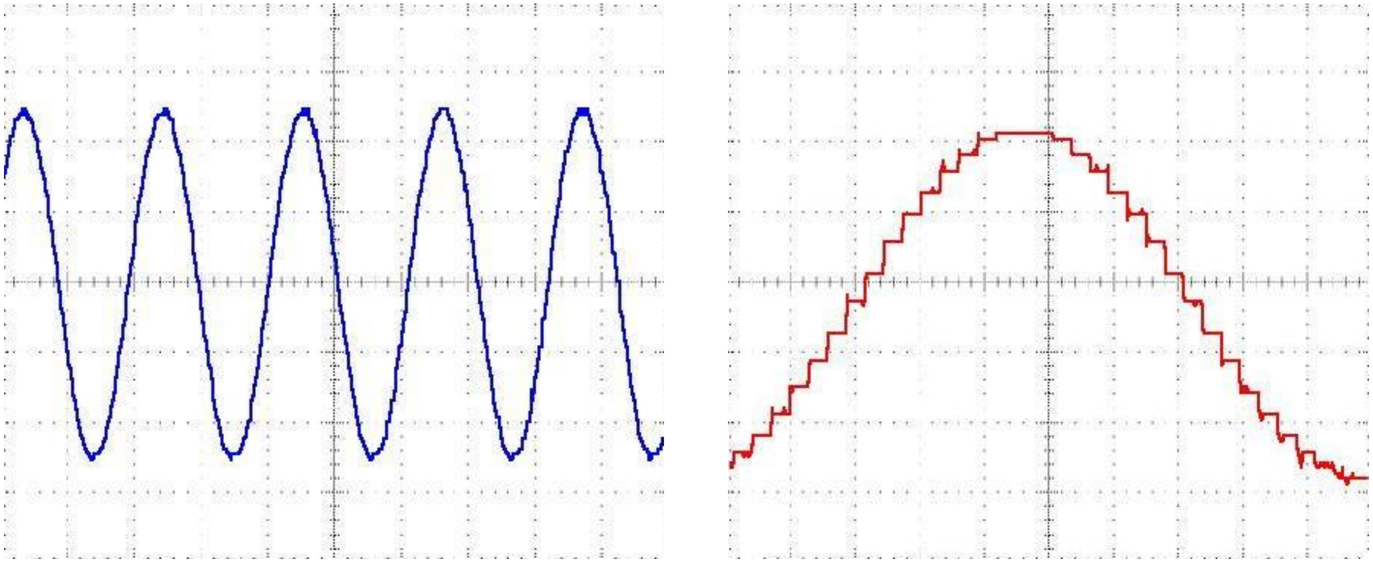
Overview

- What is DSP?
- Converting Analog into Digital
  - Electronically
  - Computationally
- How Does It Work?
  - Faithful Duplication
  - Resolution Trade-offs

What is DSP?

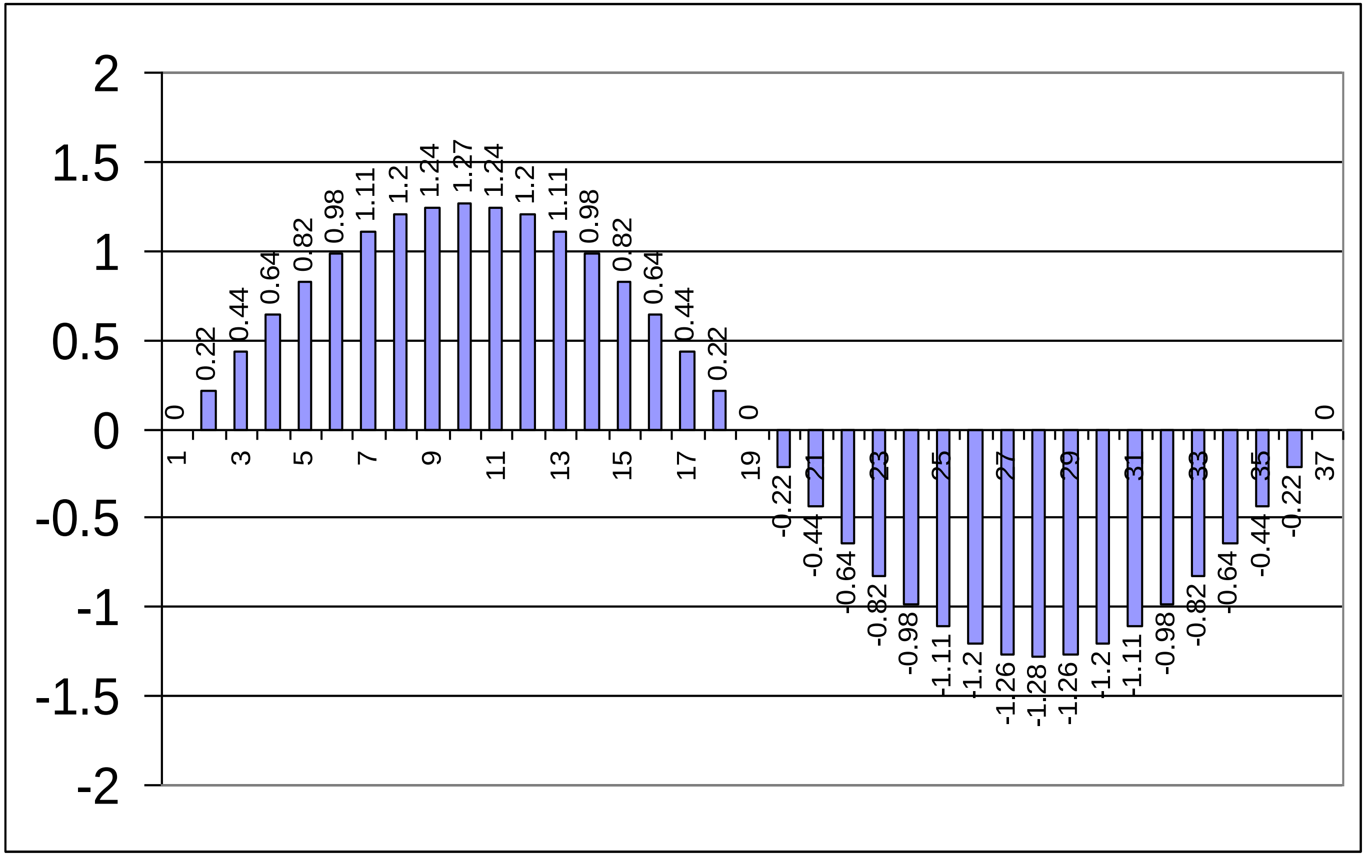
- Converting a continuously changing waveform (analog) into a series of discrete levels (digital)



What is DSP?

- The analog waveform is sliced into equal segments and the waveform amplitude is measured in the middle of each segment.
- The collection of measurements make up the digital representation of the waveform.

What is DSP?


2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.22
0.44
0.64
0.82
0.98
1.11
1.2
1.24
1.27
1.24
1.2
1.11
0.98
0.82
0.64
0.44
0.22
0
-0.22
-0.44
-0.64
-0.82
-0.98
-1.11
-1.2
-1.26
-1.28
-1.26
-1.2
-1.11
-0.98
-0.82
-0.64
-0.44
-0.22
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
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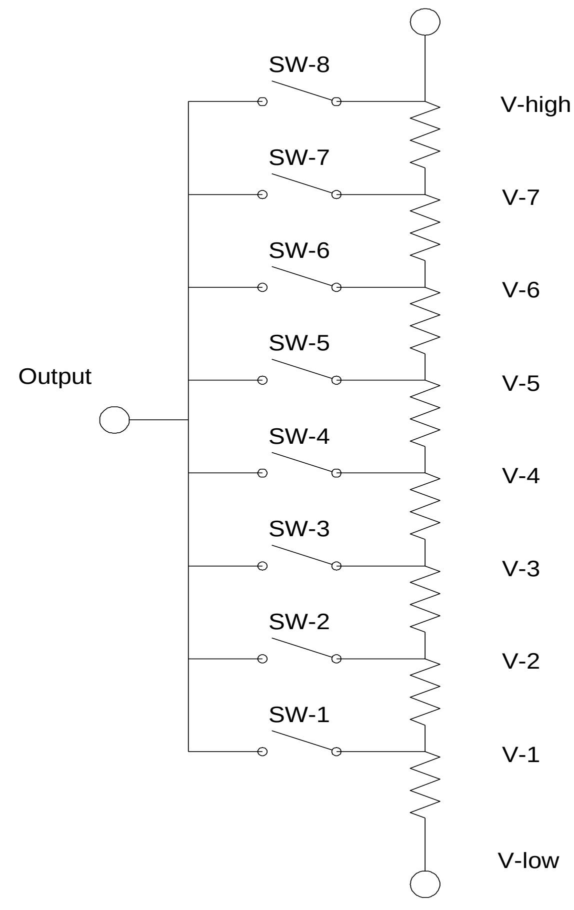
33
35
37

Converting Analog into Digital Electronically

- The device that does the conversion is called an Analog to Digital Converter (ADC).
- There is a device that converts digital to analog that is called a Digital to Analog Converter (DAC).

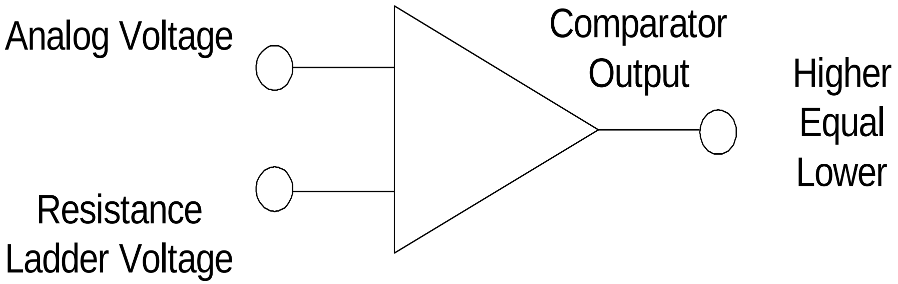
Converting Analog into Digital Electronically

- The simplest form of ADC uses a resistance ladder to switch in the appropriate number of resistors in series to create the desired voltage that is compared to the input (unknown) voltage



Converting Analog into Digital Electronically

- The output of the resistance ladder is compared to the analog voltage in a comparator
- When there is a match, the digital equivalent (switch configuration) is captured



Converting Analog into Digital Computationally

- The analog voltage can now be compared with the digitally generated voltage in the comparator.
- Through a technique called binary search, the digitally generated voltage is adjusted in steps until it is equal (within tolerances) to the analog voltage.
- When the two are equal, the digital value of the voltage is the outcome.

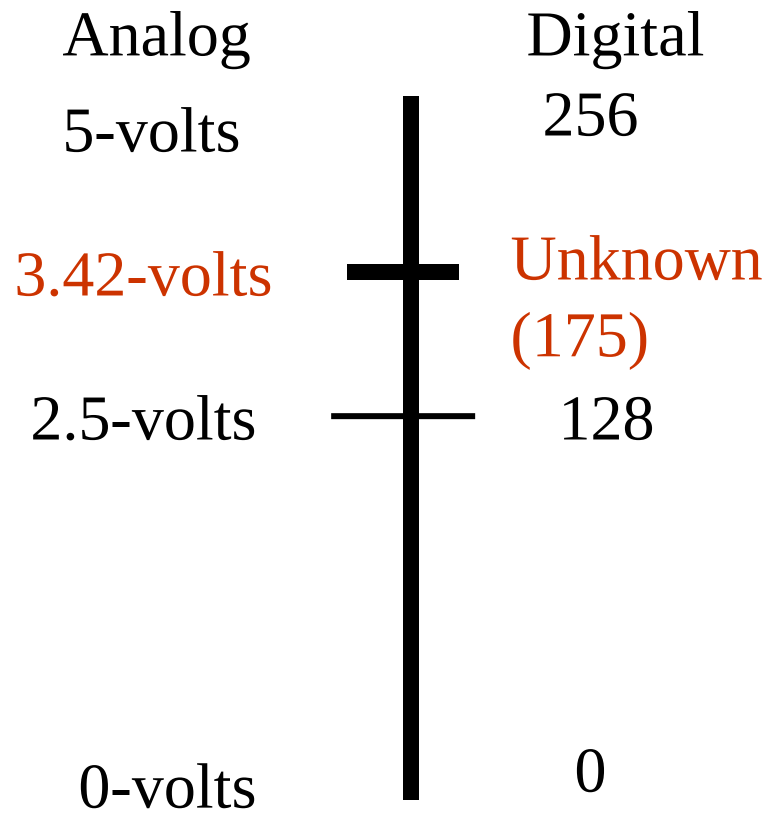
Converting Analog into Digital

Computationally

- The binary search is a mathematical technique that uses an initial guess, the expected high, and the expected low in a simple computation to refine a new guess
- The computation continues until the refined guess matches the actual value (or until the maximum number of calculations is reached)
- The following sequence takes you through a binary search computation

Binary Search

- Initial conditions
  - Expected high 5-volts
  - Expected low 0-volts
  - 5-volts 256-binary
  - 0-volts 0-binary
- Voltage to be converted
  - 3.42-volts
  - Equates to 175 binary



Binary Search

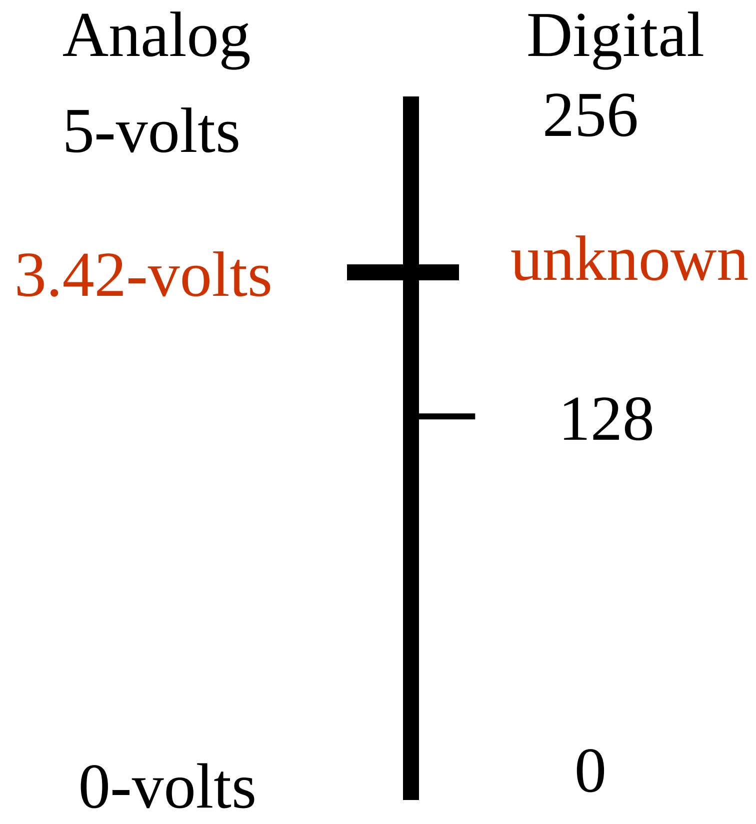
- Binary search algorithm:

$$\frac{High - Low}{2} + Low = NewGuess$$

- First Guess:

$$\frac{256 - 0}{2} + 0 = 128$$

Guess is Low

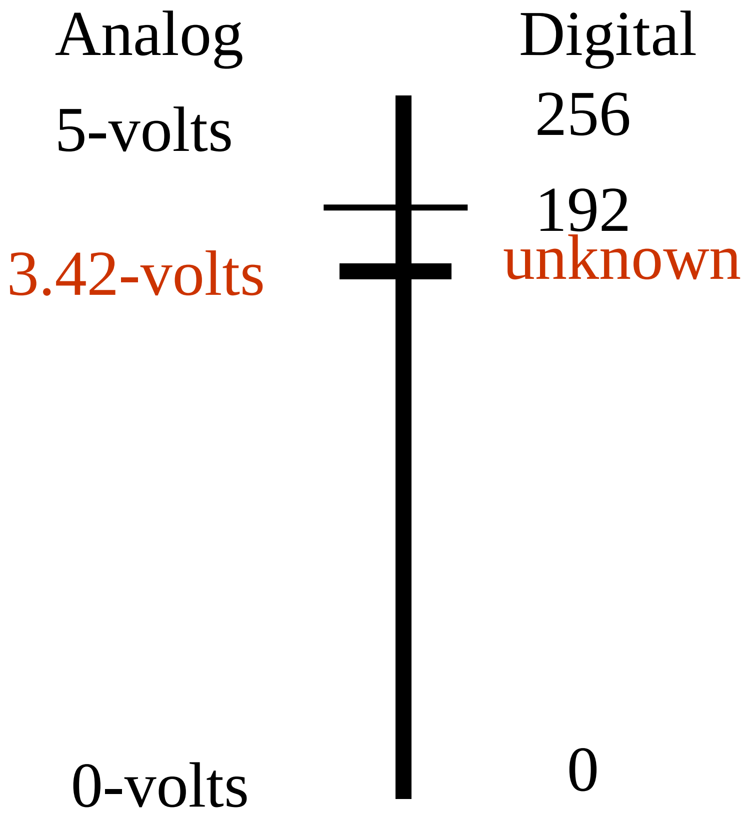


Binary Search

- New Guess (2):

$$\frac{256-128}{2}+128=192$$

Guess is High

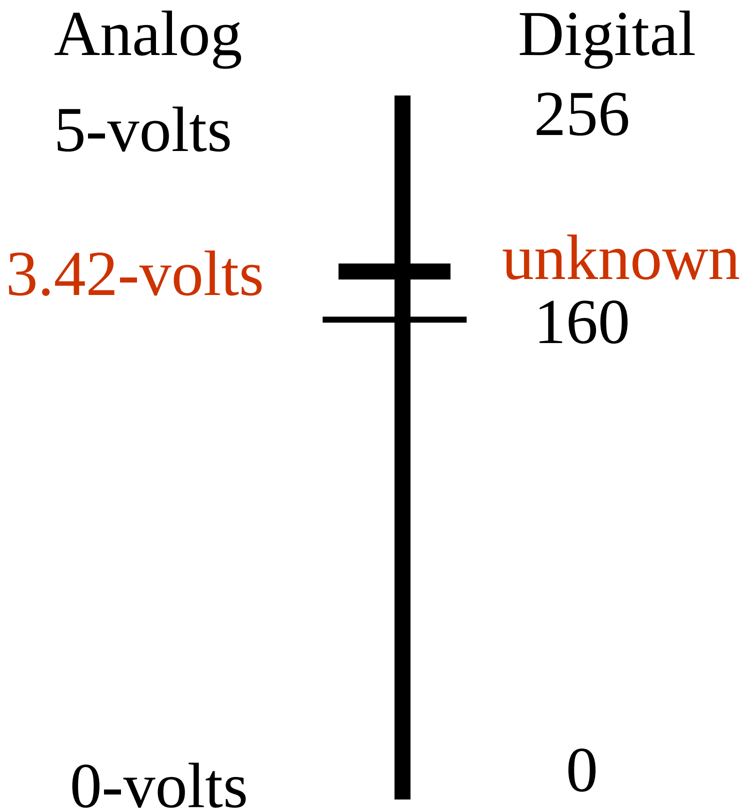


Binary Search

- New Guess (3):

$$\frac{192-128}{2}+128=160$$

Guess is Low

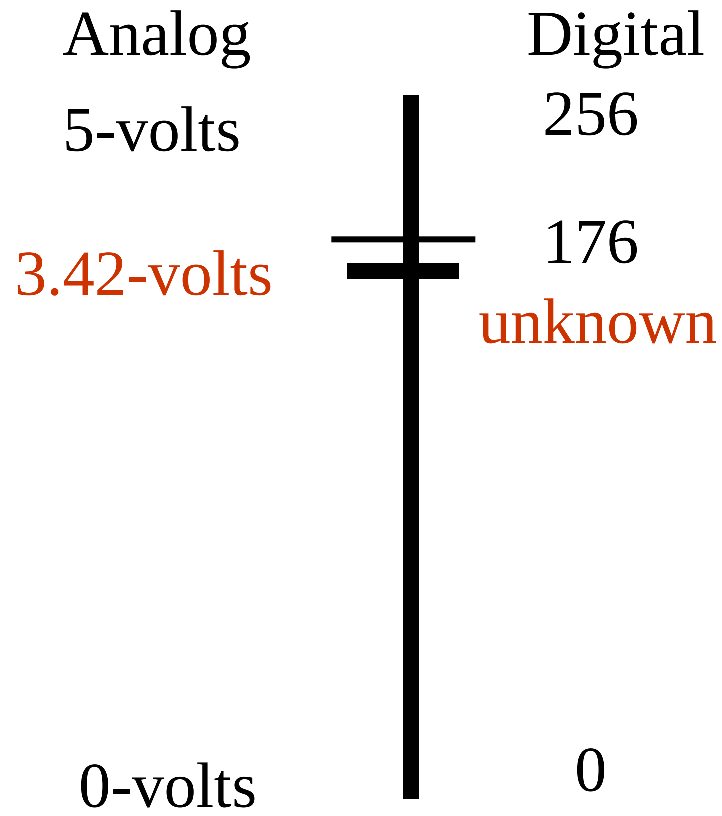


Binary Search

- New Guess (4):

$$\frac{192 - 160}{2} + 160 = 176$$

Guess is High

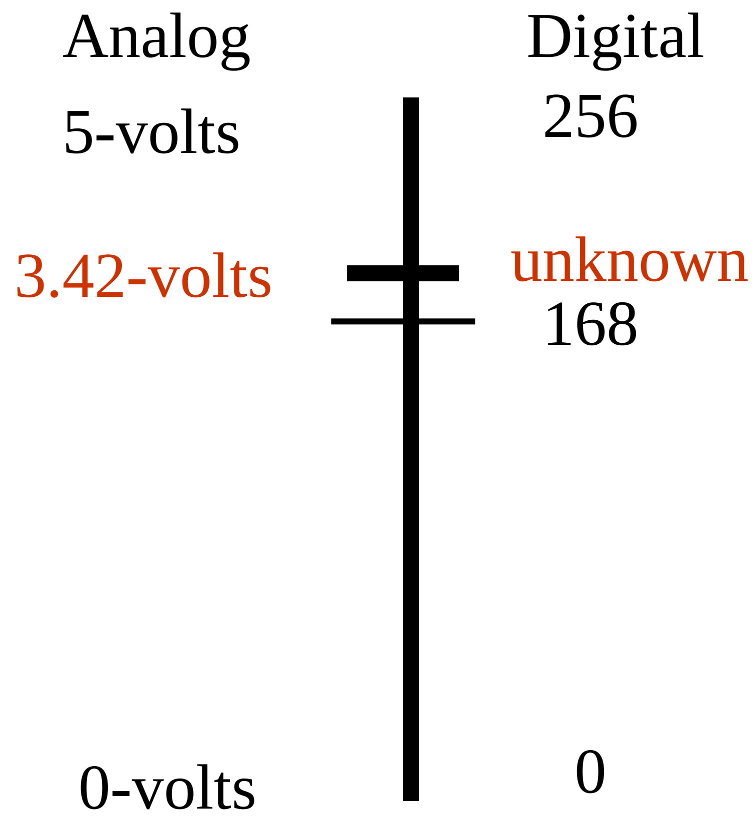


Binary Search

- New Guess (5):

$$\frac{176-160}{2}+160=168$$

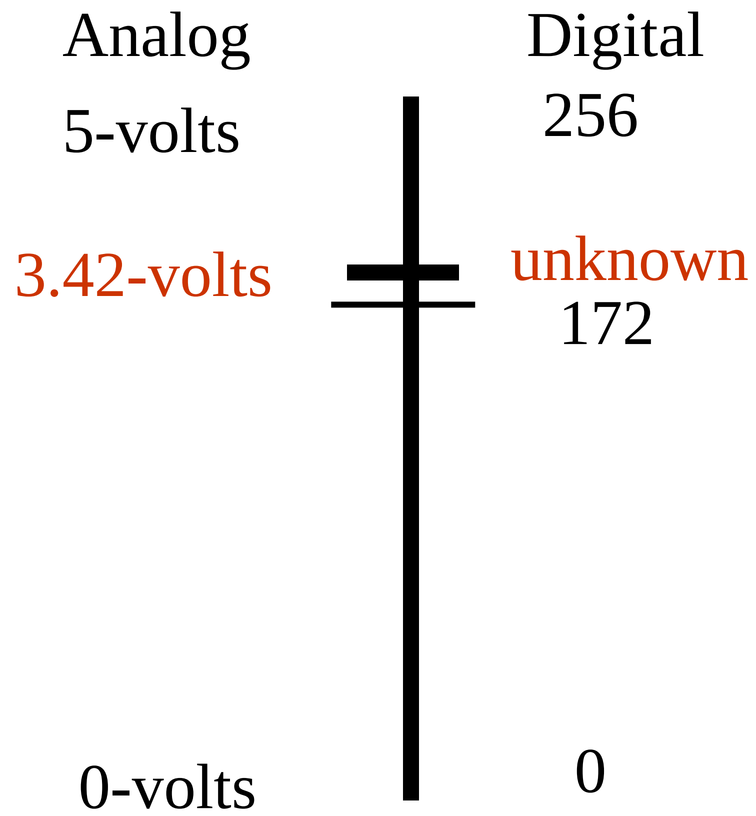
Guess is Low



Binary Search

- New Guess (6):

$$\frac{176-168}{2}+168=172$$



Guess is Low

(but getting close)

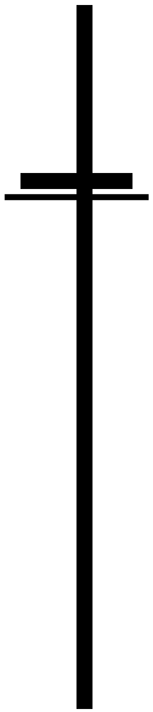
Binary Search

- New Guess (7):

$$\frac{176 - 172}{2} + 172 = 174$$

Guess is Low

(but getting really, really, close)

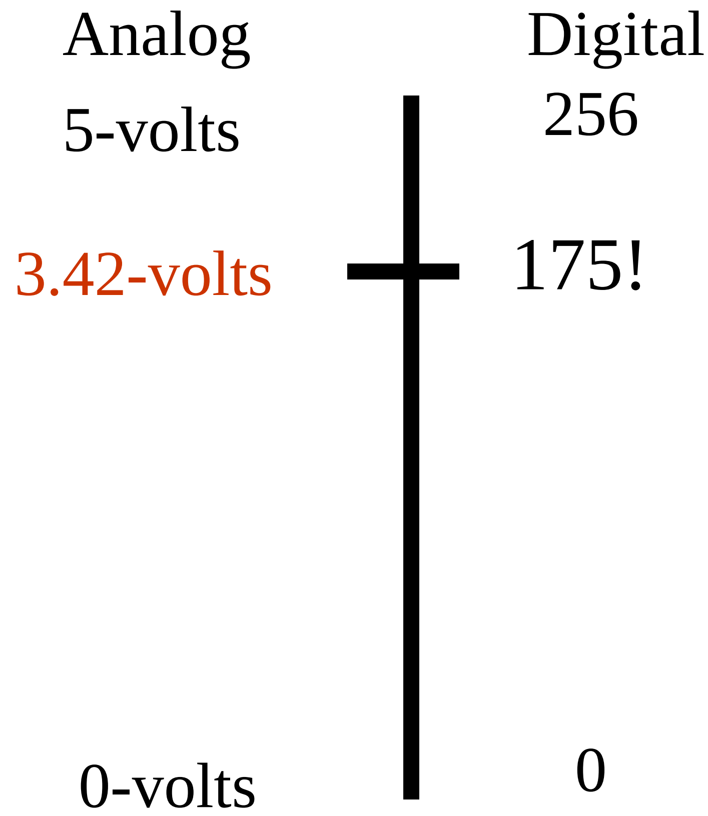


Binary Search

- New Guess (8):

$$\frac{176 - 174}{2} + 174 = 175$$

Guess is Right On



Binary Search

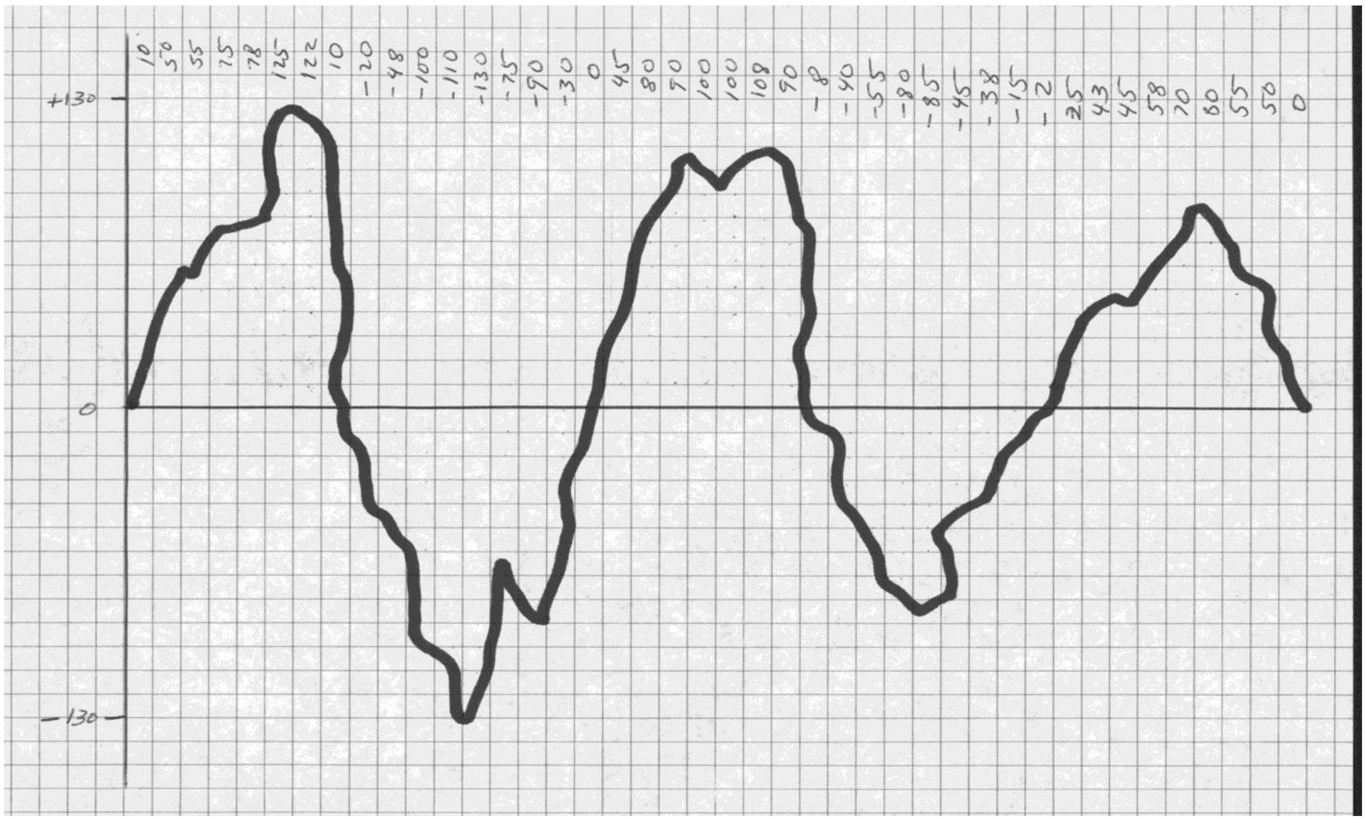
- The speed the binary search is accomplished depends on:
  - The clock speed of the ADC
  - The number of bits resolution
  - Can be shortened by a good guess (but usually is not worth the effort)

How Does It Work?

Faithful Duplication

- Now that we can slice up a waveform and convert it into digital form, let’s take a look at how it is used in DSP
- Draw a simple waveform on graph paper
  - – Scale appropriately
- “Gather” digital data points to represent the waveform

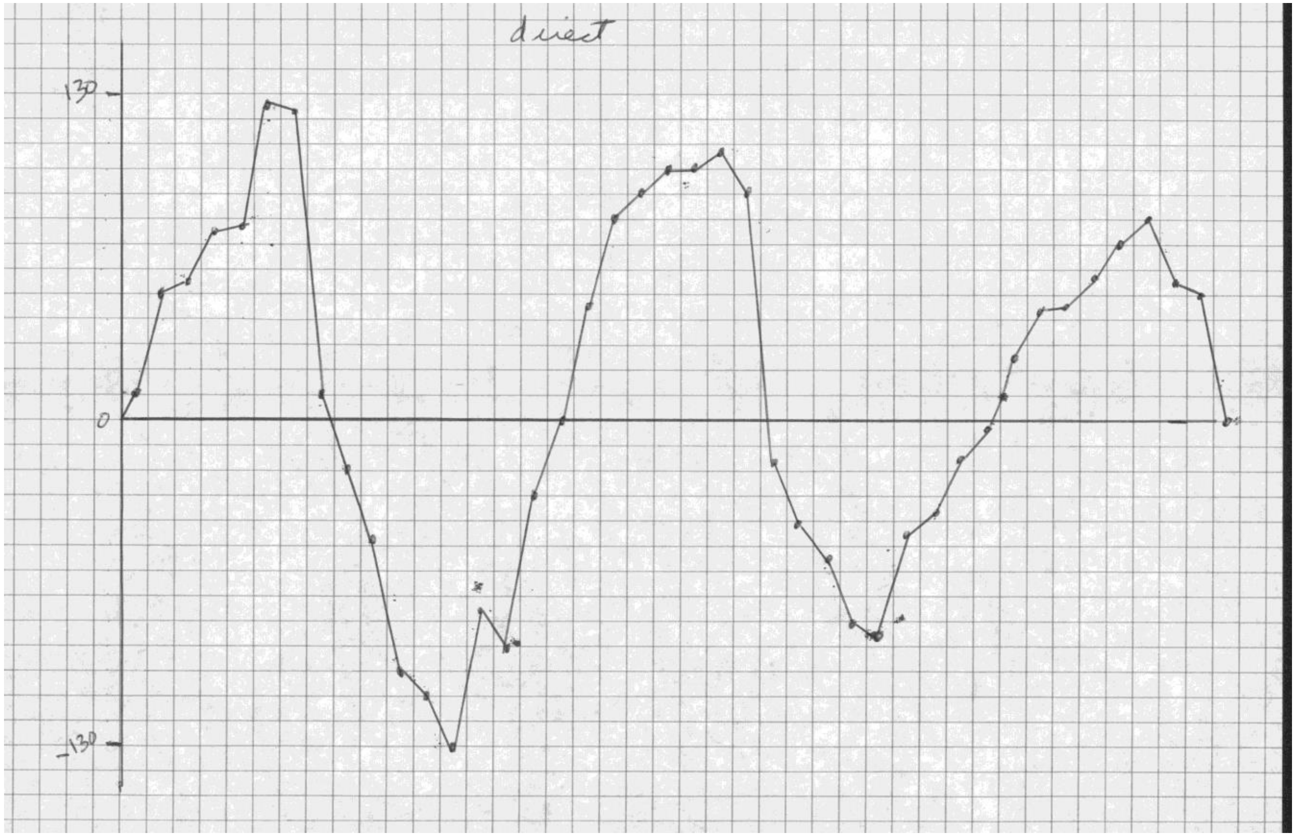
Starting Waveform Used to Create Digital Data



How Does It Work?
Faithful Duplication

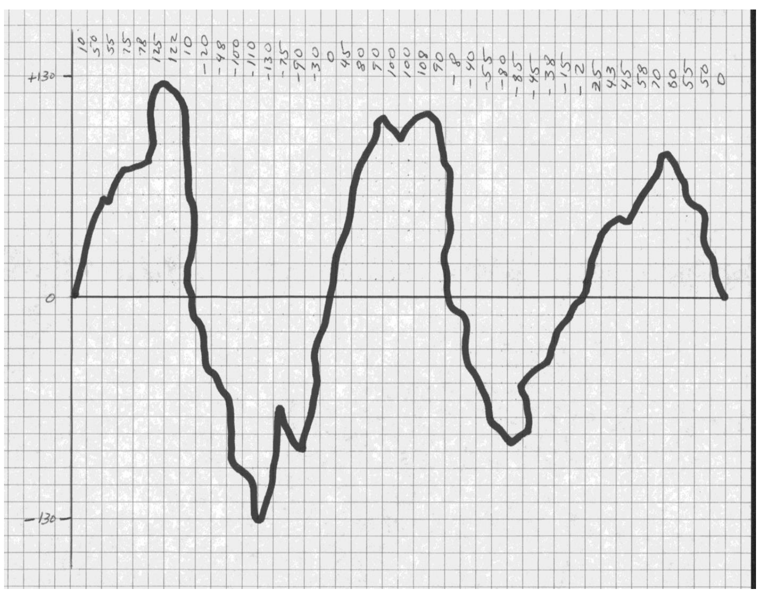
- Swap your waveform data with a partner.
- Using the data, recreate the waveform on a sheet of graph paper.

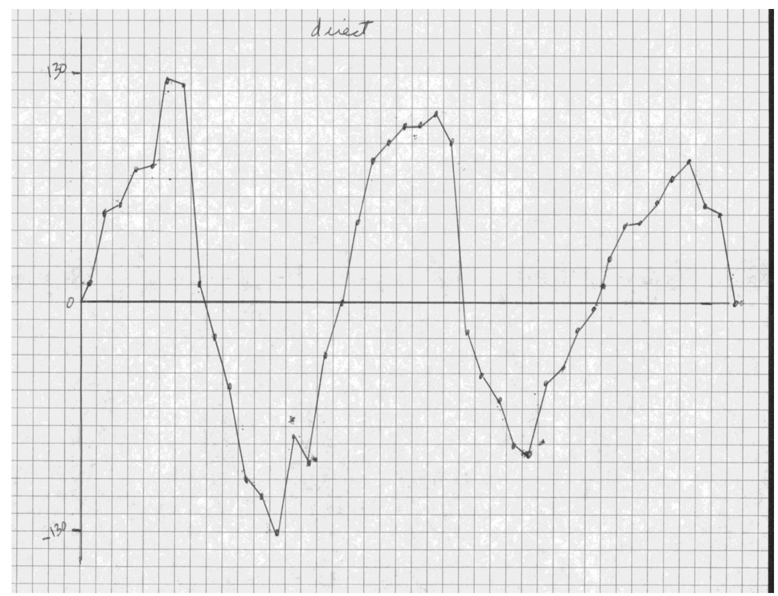
Waveform Created from Digital Data



How Does It Work?
Faithful Duplication

- Compare the original with the recreating, note similarities and differences





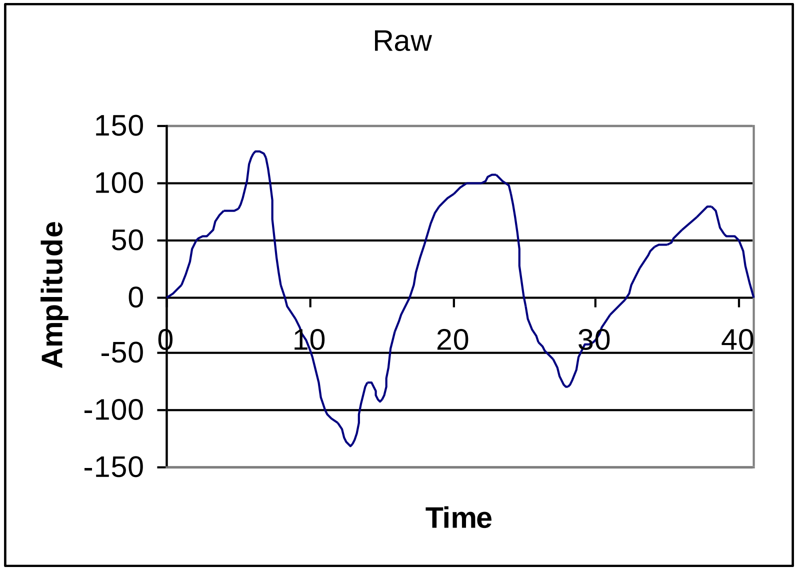
How Does It Work?
Faithful Duplication

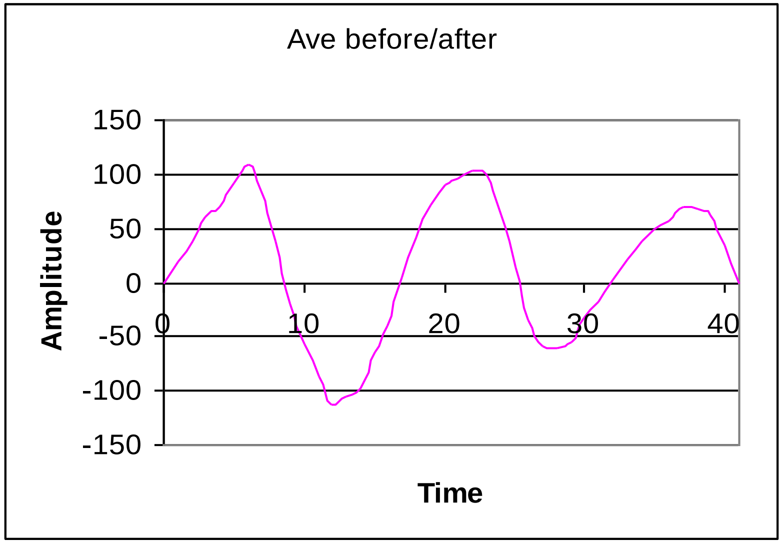
- Once the waveform is in digital form, the real power of DSP can be realized by mathematical manipulation of the data.
- Using EXCEL spreadsheet software can assist in manipulating the data and making graphs quickly.
- Let’s first do a little filtering of noise.

How Does It Work?
Faithful Duplication

- Using your raw digital data, create a new table of data that averages three data points
  - Average the point before and the point after with the point in the middle
  - Enter all data in EXCEL to help with graphing.

Noise Filtering Using Averaging

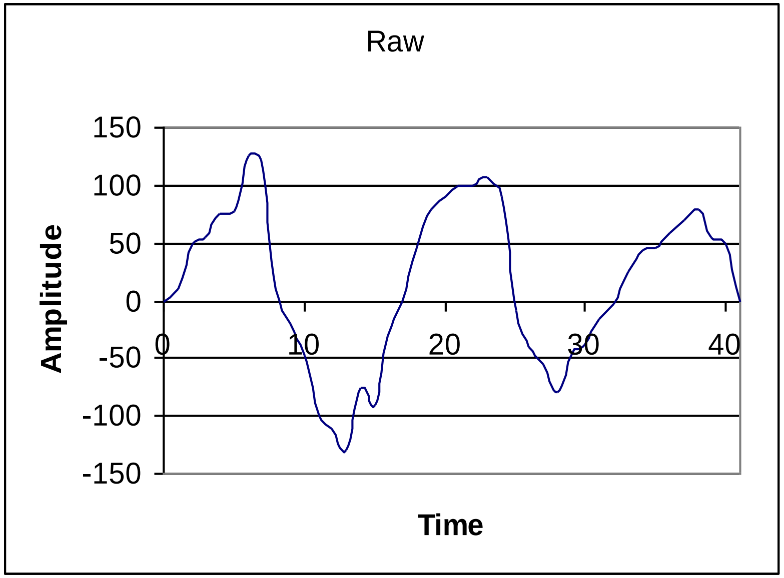


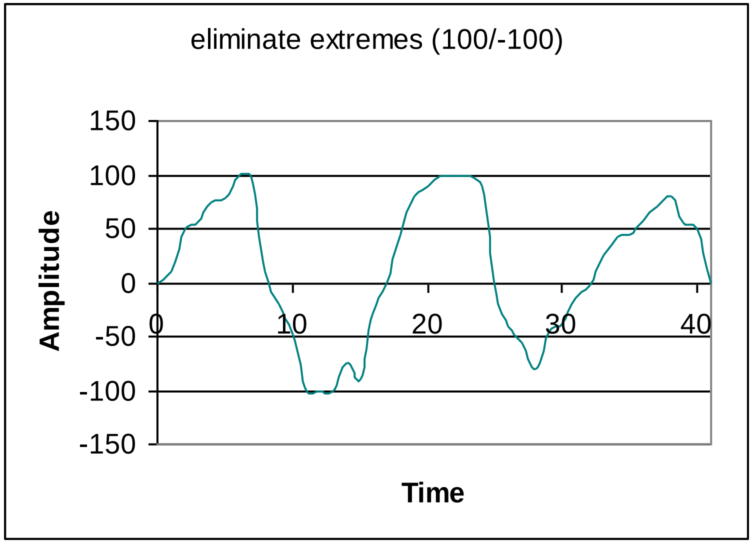


How Does It Work?
Faithful Duplication

- Let’s take care of some static crashes that cause some interference.
- Using your raw digital data, create a new table of data that replaces extreme high and low values:
  – Replace values greater than 100 with 100
  – Replace values less than -100 with -100

Clipping of Static Crashes

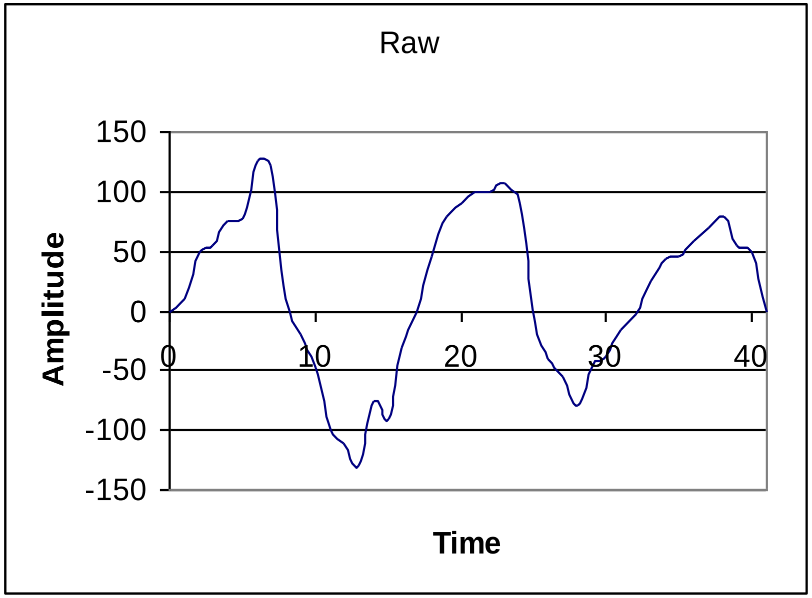


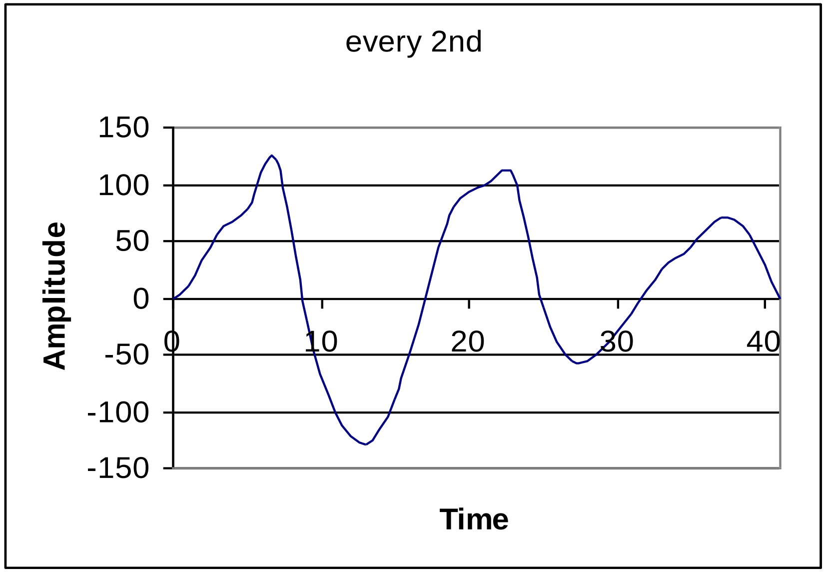


How Does It Work?
Resolution Trade-offs

- Now let's take a look at how sampling rates affect the faithful duplication of the waveform.
- Using your raw digital data, create a new table of data and delete every other data point.
- This is the same as sampling at half the rate.

Half Sample Rate

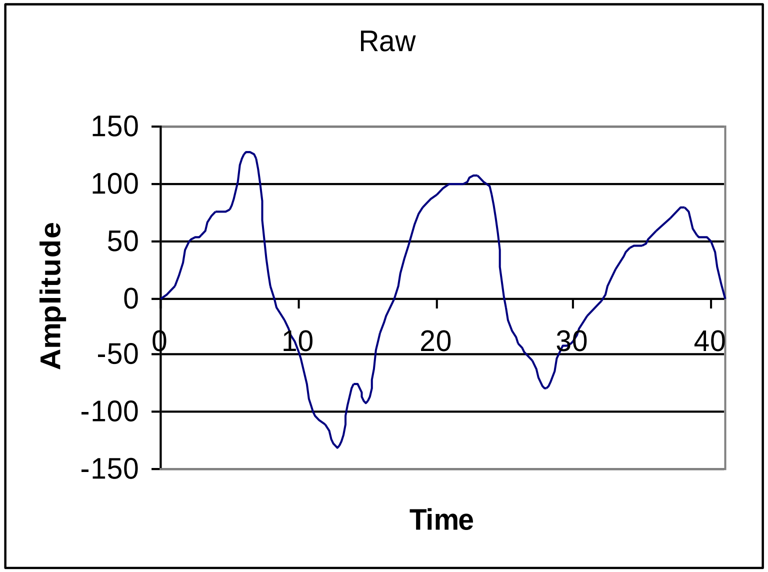


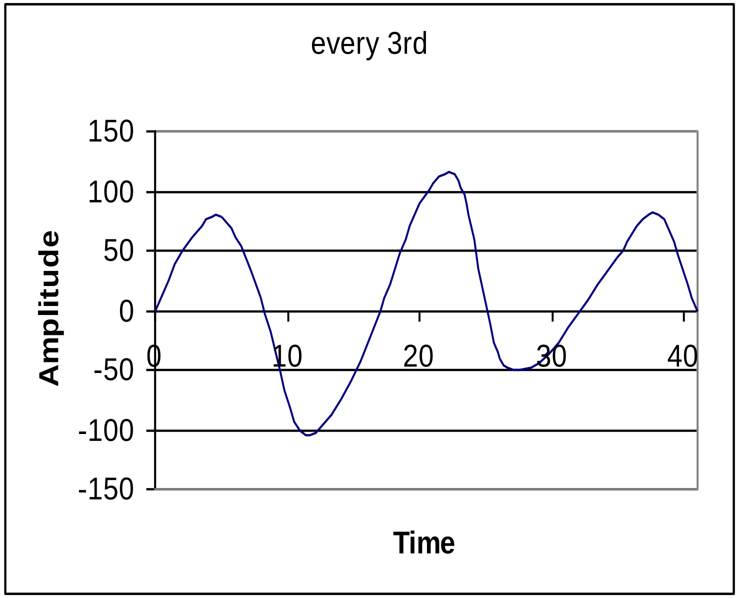


How Does It Work? Resolution Trade-offs

- Using your raw digital data, create a new table of data and delete every second and third data point.
- This is the same as sampling at one-third the rate.

1/2 Sample Rate

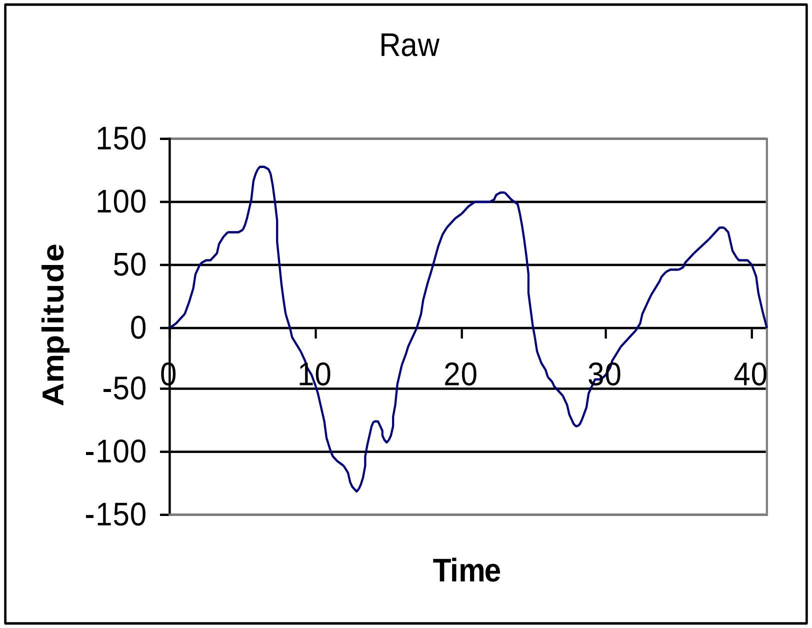


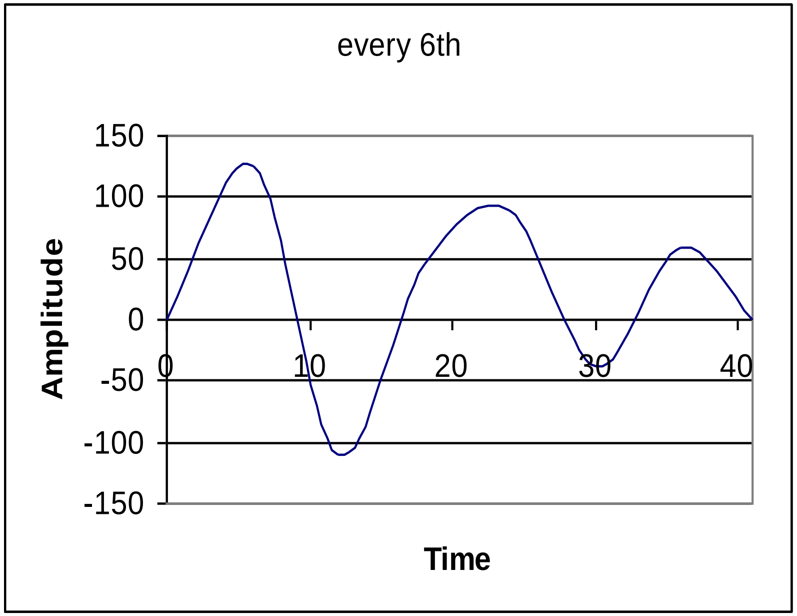


How Does It Work?
Resolution Trade-offs

- Using your raw digital data, create a new table of data and delete all but every sixth data point.
- This is the same as sampling at one-sixth the rate.

1/6 Sample Rate

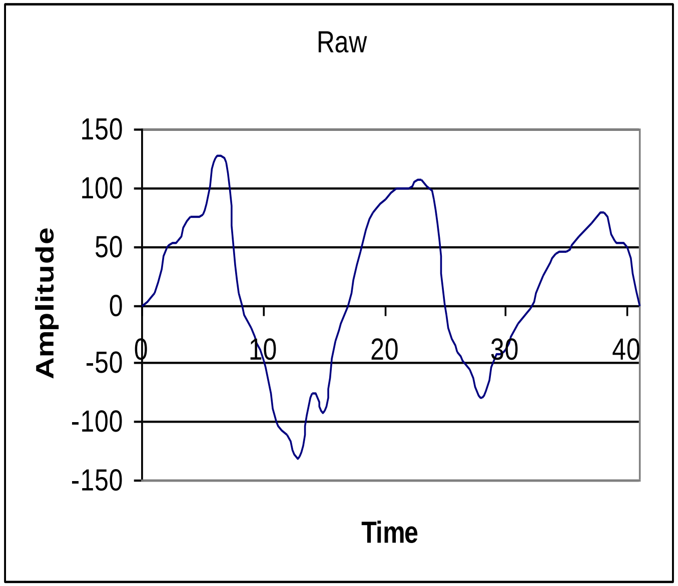


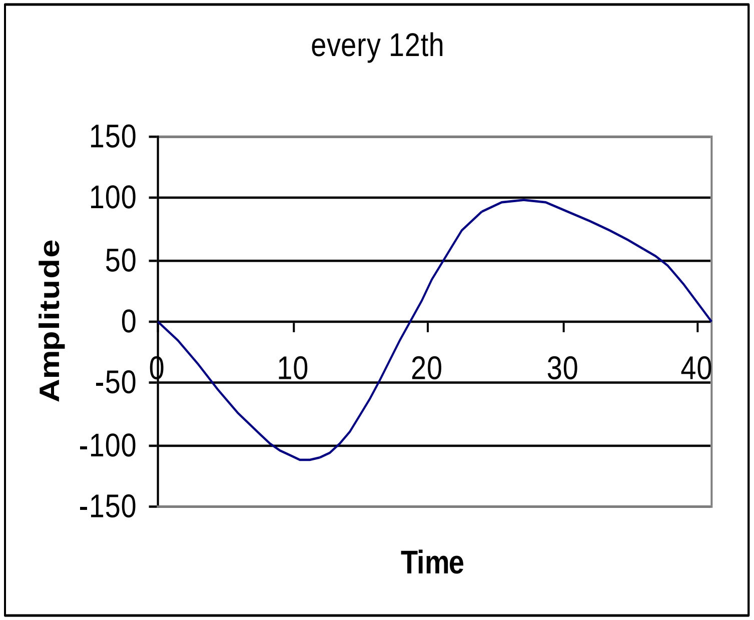


How Does It Work?
Resolution Trade-offs

- Using your raw digital data, create a new table of data and delete all but every twelfth data point.
- This is the same as sampling at one-twelfth the rate.

1/12 Sample Rate





How Does It Work?
Resolution Trade-offs

- What conclusions can you draw from the changes in sampling rate?
- At what point does the waveform get too corrupted by the reduced number of samples?
- Is there a point where more samples does not appear to improve the quality of the duplication?

How Does It Work?
Resolution Trade-offs

Bit Resolution	High Bit Count	Good Duplication	Slow
	Low Bit Count	Poor Duplication	Fast
Sample Rate	High Sample Rate	Good Duplication	Slow
	Low Sample Rate	Poor Duplication	Fast